MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

ETM2016 – ANALOG COMMUNICATIONS
(TE)

7 MARCH 2019
9.00 a.m. – 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 10 pages with 4 Questions only.
2. Attempt **ALL** questions. Each question carries an equal total mark and the mark distribution for each question is given.
3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) A sinusoidal voltage $E\sin\omega t$, where t is time, is passed through a half-wave rectifier that clips the negative portion of the wave shown in Figure Q1.1. Find the Fourier series of the resulting periodic function. The formula is

$$u(t) = \begin{cases} 0 & if \quad -\tau < t < 0, \\ E\sin\omega t & if \quad 0 < t < \tau \end{cases} \qquad \tau = \frac{\pi}{\omega}$$

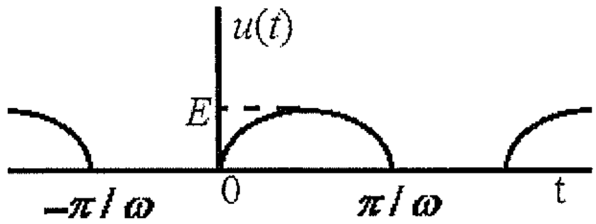

Figure Q1.1 [10 marks]

(b) Figure Q1.2 shows the plot of the Inverse Fourier Transform of $S(f)$ given by

$$s_m(t) = (A_c + A_x\cos(2\pi f_x t))\cos(2\pi f_c t)$$

(i) What is the value of the frequency f_c?

[2 marks]

(ii) What is the value of the frequency f_x?

[2 marks]

(iii) Calculate A_c and A_x.

[4 marks]

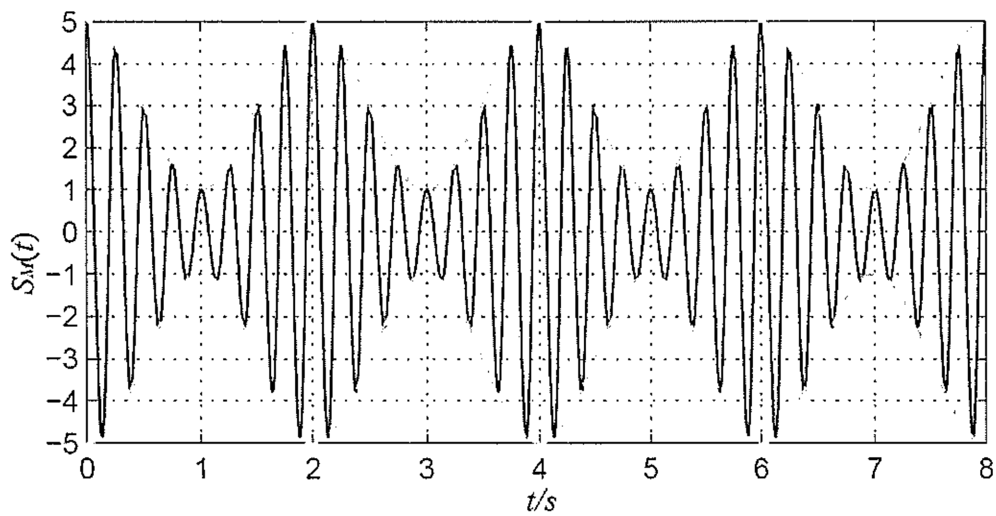

Figure Q1.2

Continued...

(c) Figure Q1.3 shows the amplitude spectrum of frequency domain signal $Y(\omega)$.

(i) Determine the values of the frequencies at $\omega = 90$ rad/s, $\omega = 100$ rad/s and $\omega = 110$ rad/s.

[3 Marks]

(ii) Convert $Y(\omega)$ into its equivalent time domain signal $y(t)$ where $\theta_n = 0$ for all n.

[4 Marks]

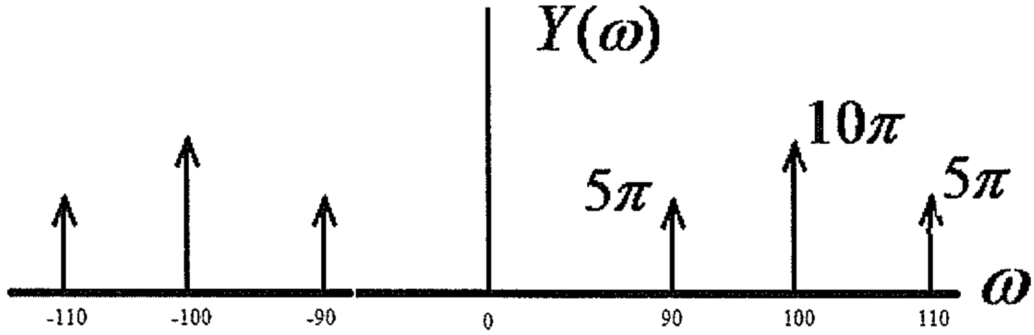

Figure Q1.3

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Question 2

(a) An angle modulated signal has the form

$$u(t) = 100\cos\left[2\pi f_c t + 4\sin 2\pi f_m t\right]$$

where f_c=10 MHz and f_m=1000 MHz

(i) Assume that this is an FM signal; determine the modulation index and the transmitted signal bandwidth.

[3 Marks]

(ii) Assuming that this is a PM signal determine the modulation index and the transmitted signal bandwidth.

[3 Marks]

(b) Balanced modulator is used to generate double-sideband suppressed-carrier modulation (DSB-SC) signal. With a suitable block diagram, discuss how to generate a DSB-SC signal. Please aid your answer with complete mathematical derivation.

[13 Marks]

(c) The tone modulation double-sideband large carrier (DSB-LC) AM waveform is given by

$$\varphi(t) = (A - 5\cos 100t)\cos 1000t$$

The power efficiency of the system is 1/19.

(i) Determine A

[3 Marks]

(ii) Sketch the magnitude spectrum of $\varphi(t)$.

[3 Marks]

Continued...

Question 3

(a) An angle modulated signal is given as below

$$\varphi_{EM}(t) = 10\cos\left(2\pi.10^{5}t + 2\sin 2\pi 2000t\right)$$

It is input to a frequency multiplier with a factor $N = 5$ to produce the FM signal $y(t)$.

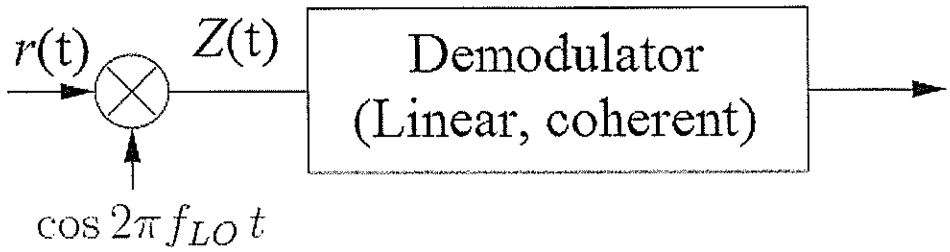
(i) Define in words the frequency deviation and determine its value.

[2+4 Marks]

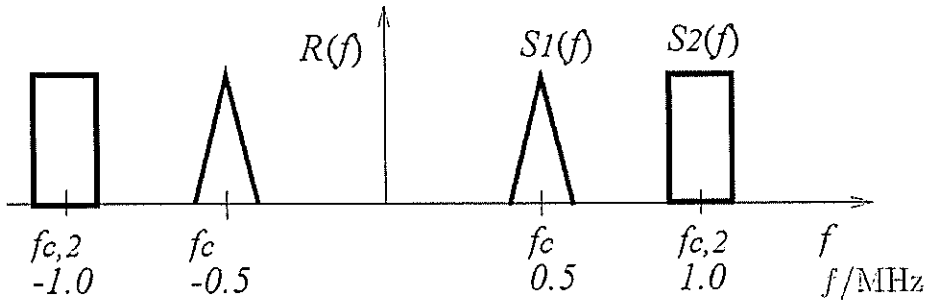
(ii) Estimate the bandwidth, as per Carson's rule, of the signal $y(t)$. Is this narrowband FM?

[2+1 Marks]

(b) We want to receive a medium wave signal $s_1(t)$ transmitted at carrier frequency $f_c = 0.5$ MHz. The system proposed in Figure Q3.1 first down-converts the received signal $r(t)$ to a constant intermediate frequency $f_{IF} = 0.25$ MHz. Then the signal is demodulated. The frequency of the local oscillator is $f_{LO} = 0.75$ MHz.



$r(t)$ consists of our desired signal $s_1(t)$ and an interfering signal $s_2(t)$ with the same bandwidth as $s_1(t)$ at carrier frequency $f_{c,2} = 1.0$ MHz. The spectra are given in Figure Q3.2.



Sketch the spectrum $Z(f)$ of the signal $z(t)$ at the output of the down converter. Label the frequency axis only.

[6 Marks]

(c) With the aid of a block diagram, describe the process of FM-to-AM conversion in demodulating an FM signal.

[10 Marks]

Continued...

Question 4

(a) Based on the following properties of an FM signal generation:

- The carrier frequency is 1 MHz and the power of the FM signal is 50 W,
- The modulating signal $m(t) = 4\cos(2\pi 100t)$,
- The frequency deviation constant is 500π rad/sec/volt,

(i) Determine the modulation index.

(ii) Find the power and the bandwidth using Carson's rule and Bessel Function

[12 Marks]

(b) A certain communication channel is characterized by 90dB attenuation and additive white noise with power-spectral density of $N_0/2 = 0.5 \times 10^{-14}$ W/Hz. The bandwidth of the message signal is 1.5 MHz and its amplitude is uniformly distributed in the interval $[-1, 1]$. If we require that the transmitter power 15kW, find the signal to noise ratio (SNR) after demodulation. Express the SNR in dB.

[8 Marks]

(c) A single sideband modulated received signal $\boldsymbol{S_{BP}(t)}$ shall be demodulated with a heterodyne receiver. The magnitude spectrum $|\boldsymbol{S_{BP}(f)}|$ of $\boldsymbol{S_{BP}(t)}$ is shown in **Figure Q4.1**.

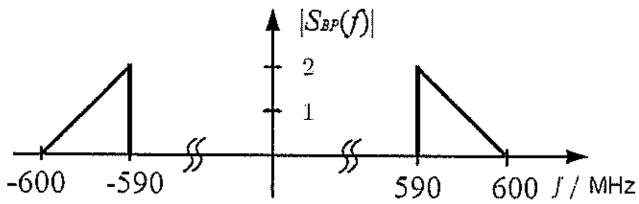


Figure Q4.1

Figure Q4.2 shows the structure of the heterodyne receiver. The frequency of the first mixer is given by $f_{LO} = 450$MHz and the frequency of the second mixer is given by $f_{IF} = 150$ MHz.

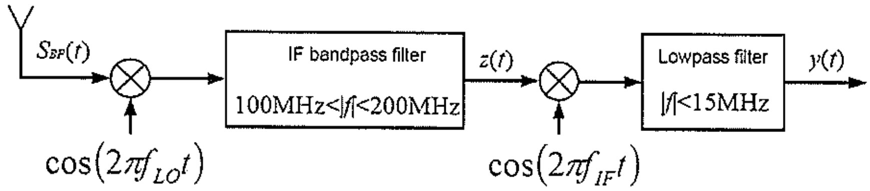


Figure Q4.2

(i) Draw the magnitude spectrum $|Z(f)|$ of the IF signal $z(t)$ at the input of the second mixer in the range of $-250\text{MHz} \le f \le 250\text{MHz}$. Label the axis correctly.

[2.5 Marks]

(ii) Draw the magnitude spectrum $|Y(f)|$ of the demodulated received signal $y(t)$ in the range of $-50\text{MHz} \le f \le 50\text{MHz}$. Label the axis correctly.

[2.5 Marks]

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Appendix I

Trigonometric Preliminaries

1. $\sin(n\pi) = 0,\ n = \text{integer}$
2. $\cos(n\pi) = (-1)^n = \begin{cases} 1, & n = even \\ -1, & n = odd \end{cases}$
3. $\sin^2 x = \frac{1}{2}(1 - \cos 2x)$
4. $\cos^2 x = \frac{1}{2}(1 + \cos 2x)$
5. $\sin x \sin y = \frac{1}{2}\left[-\cos(x+y) + \cos(x-y)\right]$
6. $\cos x \cos y = \frac{1}{2}\left[\cos(x+y) + \cos(x-y)\right]$
7. $\sin x \cos y = \frac{1}{2}\left[\sin(x+y) + \sin(x-y)\right]$

$$\sin\theta = \frac{1}{2j}\left[e^{j\theta} - e^{-j\theta}\right]$$

$$\cos\theta = \frac{1}{2}\left[e^{j\theta} + e^{-j\theta}\right]$$

$$x\cos(ax)dx = \frac{x\sin(ax)}{a} + \frac{\cos(ax)}{a^2}$$

$$x\sin(ax)dx = \frac{-x\cos(ax)}{a} + \frac{\sin(ax)}{a^2}$$

Continued…

Appendix II

Fourier Transform Pairs

$x(t)$	$X(f)$
$\delta(t)$	1
$\delta(t-t_o)$	$e^{-j2\pi f t_o}$
1	$\delta(f)$
$e^{j2\pi f_o t}$	$\delta(f-f_o)$
$u(t)$	$\frac{1}{2}\delta(f)+\frac{1}{j2\pi f}$
$e^{-at}u(t)$	$\frac{1}{a+j2\pi f}$, for $a>0$
$e^{at}u(-t)$	$\frac{1}{a-j2\pi f}$, for $a>0$
$e^{-a\lvert t\rvert}$	$\frac{2a}{a^2+(2\pi f)^2}$, for $a>0$
$t^n e^{-at}u(t)$	$\frac{n!}{(a+j2\pi f)^{n+1}}$, for $a>0$
$rect\left(\frac{t}{T}\right)$	$T\mathrm{sinc}(fT)$
$\mathrm{sinc}(2Wt)$	$\frac{1}{2W}rect\left(\frac{f}{2W}\right)$
$\Delta\left(\frac{t}{T}\right)$	$\frac{T}{2}\mathrm{sinc}^2\left(\frac{fT}{2}\right)$
$W\mathrm{sinc}^2(Wt)$	$\Delta\left(\frac{f}{2W}\right)$
$e^{-\pi t^2}$	$e^{-\pi f^2}$

Continued...

Appendix III

Fourier Transform Pairs and Properties

$\cos(2\pi f_o t)$	$\frac{1}{2}\delta(f-f_o)+\frac{1}{2}\delta(f+f_o)$
$\sin(2\pi f_o t)$	$\frac{1}{2j}[\delta(f-f_o)-\delta(f+f_o)]$
$\operatorname{sgn}(t)=\begin{cases}1 & t>0\\ -1 & t<0\end{cases}$	$\frac{1}{j\pi f}$
$\frac{1}{\pi t}$	$-j\operatorname{sgn}(f)$
$\sum_{i=-\infty}^{\infty}\delta(t-iT_o)$	$\frac{1}{T_o}\sum_{n=-\infty}^{\infty}\delta(f-\frac{n}{T_o})$
$e^{-at}\cos(2\pi f_o t)u(t)$	$\frac{a+j2\pi f}{(a+j2\pi f)^2+(2\pi f_o)^2}$, for $a>0$
$e^{-at}\sin(2\pi f_o t)u(t)$	$\frac{2\pi f_o}{(a+j2\pi f)^2+(2\pi f_o)^2}$, for $a>0$

Let $x(t)\Leftrightarrow X(f)$, $x_1(t)\Leftrightarrow X_1(f)$ and $x_2(t)\Leftrightarrow X_2(f)$; and

a, b, t_o and f_o scalar quantities.

Linearity	$ax_1(t)+bx_2(t)\Leftrightarrow aX_1(f)+bX_2(f)$
Conjugation	$x^*(t)\Leftrightarrow X^*(-f)$
Duality	$X(t)\Leftrightarrow x(-f)$
Scaling ($a\neq 0$)	$x(at)\Leftrightarrow \frac{1}{\lvert a\rvert}X\left(\frac{f}{a}\right)$
Time Shifting	$x(t-t_o)\Leftrightarrow X(f)e^{-j2\pi f t_o}$
Frequency Shifting	$x(t)e^{j2\pi f_o t}\Leftrightarrow X(f-f_o)$
Modulation	$x(t)\cos(2\pi f_0 t)\Leftrightarrow \frac{1}{2}X(f-f_0)+\frac{1}{2}X(f+f_0)$
Time Differentiation	$\frac{d^n}{dt^n}x(t)\Leftrightarrow (j2\pi f)^n X(f)$
Frequency Differentiation	$(-jt)^n x(t)\Leftrightarrow \frac{d^n}{df^n}X(f)$

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Appendix IV

Bessel Function Table

n	$\beta = 0$	$\beta = 0.05$	$\beta = 0.1$	$\beta = 0.2$	$\beta = 0.3$	$\beta = 0.5$	$\beta = 0.7$	$\beta = 1$	$\beta = 2$	$\beta = 3$	$\beta = 5$	$\beta = 7$	$\beta = 8$	$\beta = 10$
0	1.000	0.999	0.998	0.990	0.978	0.938	0.881	0.765	0.224	-0.260	-0.178	0.300	0.172	-0.246
1		0.025	0.050	0.100	0.148	0.242	0.329	0.440	0.577	0.339	-0.328	-0.005	0.235	0.043
2			0.001	0.005	0.011	0.031	0.059	0.115	0.353	0.486	0.047	-0.301	-0.113	0.255
3					0.001	0.003	0.007	0.020	0.129	0.309	0.365	-0.168	-0.291	0.058
4							0.001	0.002	0.034	0.132	0.391	0.158	-0.105	-0.220
5									0.007	0.043	0.261	0.348	0.186	-0.234
6									0.001	0.011	0.131	0.339	0.338	-0.014
7										0.003	0.053	0.234	0.321	0.217
8											0.018	0.128	0.223	0.318
9											0.006	0.059	0.126	0.292
10											0.001	0.024	0.061	0.207
11												0.008	0.026	0.123
12												0.003	0.010	0.063
13												0.001	0.003	0.029
14													0.001	0.012
15														0.005
16														0.002
17														0.001

	N		N		N		N
$\beta = 0.05$	1	$\beta = 0.7$	4	$\beta = 5$	10	$\beta = 20$	28
$\beta = 0.1$	2	$\beta = 0.8$	4	$\beta = 6$	12	$\beta = 25$	34
$\beta = 0.2$	2	$\beta = 0.9$	4	$\beta = 7$	13	$\beta = 30$	39
$\beta = 0.3$	3	$\beta = 1$	4	$\beta = 8$	14	$\beta = 35$	45
$\beta = 0.4$	3	$\beta = 2$	6	$\beta = 9$	15	$\beta = 40$	50
$\beta = 0.5$	3	$\beta = 3$	7	$\beta = 10$	17	$\beta = 45$	55
$\beta = 0.6$	3	$\beta = 4$	9	$\beta = 15$	22	$\beta = 50$	61

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